Title of the workshop linked to the ISMICT 2011 conference (www.ismict2011.org): Ultrasound dedicated to medical applications in the frame of the FP7 ICT European project ULTRAsponder

30th March 2011, 1:30 PM to 5:30 PM, Grand Hotel Suisse Majestic: Av. des Alpes 45, Montreux

ultrasponder

Organisers

Dr. Cyril Lafon, INSERM U556, 151 Cours Albert Thomas, F-69424 LYON Cedex 03, France
E-mail: cyril.lafon@inserm.fr, direct phone: 0033 (0) 4 72 68 19 20

Dr. Catherine Dehollain: Ecole Polytechnique Fédérale de Lausanne (EPFL), RF IC research group GR-SCI-STI, SCI STI CD, Station 11, CH-1015 Lausanne, Switzerland.
E-mail: catherine.dehollain@epfl.ch, direct phone: 0041 (0) 21 693 69 71, web page: rfic.epfl.ch

Web page of the ULTRAsponder project

www.ultrasponder.org

Summary of the ULTRAsponder project

This workshop is devoted to the ULTRAsponder project. The presentations are focused on **remote powering and communications through ultrasound**, on **low power data acquisition and low power digital processing** as well as on the use on **ultrasound for the monitoring of the heart as well as medical treatments**.

The FP7 ICT European Project **ULTRAsponder** aims at developing a new system with a high degree of **reliability and accuracy of the clinical data**, while providing the patients with high level of safety and user friendliness. Though the project intends to propose a general solution to several possible pathologies, such as acute diabetes, epilepsy and other debilitating neurological disorders, it focuses its efforts on one **demonstrator devoted to chronic cardiac diseases**. For this specific application, **continuous monitoring** is particularly important to follow the day and night heart activity, thus allowing to understand **how the heart reacts** to different kinds of **stresses**, to different kinds of **activities** and to different sorts of **medications**. A continuous monitoring of a patient can also give the physicians the possibility to make a **direct comparison** of the actual patient condition with a past condition (one day, one week or one month earlier). Therefore continuous monitoring is a major leap forward in the diagnosis and the treatment of **cardiac congestive heart failure** (CHF).

ULTRAsponder aims at developing an innovative technology based on **ultrasonic telemetry techniques**, for communication between one sensor deeply implanted in the human body (**the transponder**) and a **control unit** which is used for both **wirelessly recharging** the implanted device and **transmitting the received information** to the external world.

Registration

The registration is mandatory by using the web page of the ISMICT 2011 conference.

Fees: the workshop is free of charge.

Detailed program of the workshop: See next page

Program of the workshop
entitled
Ultrasound dedicated to medical applications

13:10: Opening of the desk at the entrance of the room

13:30: Opening of the workshop, Cyril Lafon, INSERM, Unit U556, Lyon, France

13:40: Design and optimization of remotely powered RFID systems and sensor nodes
Author: Catherine Dehollain, Ecole Polytechnique Fédérale de Lausanne (EPFL), RF IC group, Lausanne, Switzerland

14:05: European project ULTRAsponder dedicated to the design of an ultrasonic transponder system
Authors: Catherine Dehollain and Francesco Mazzilli, EPFL, RF IC group, Lausanne, Switzerland

14:30: Ultrasound backscattering for deep-implanted devices: communication and energy challenges
Author: Dominique Bovey, university of applied sciences of western Switzerland, School HEIG-VD, Institute of Information and Communication Technologies (IICT), Switzerland

14:55: In vivo ultrasonic transponder system for biomedical applications
Authors: Jacob Bergsland (Oslo University Hospital, Norway) and Rogier Receveur (Medtronic Bakken Research Center, the Netherlands)

From 15:20 to 15:50: Coffee break

15:50: Detection of deeply-implanted impedance-switching devices using ultrasound Doppler
Authors: Jean-Martial Mari, Cyril Lafon, Jean Yves Chapelon, INSERM, Unit U556, Lyon, France

16:15: Shockwaves and high intensity focused ultrasound for the non invasive treatment of kidney stones and prostate cancer
Author: Emmanuel Blanc, C.T.O. EDAP-TMS, Lyon, France

16:40: Remotely-powered telemetry of the human metabolism for applications in personalized therapy
Author: Sandro Carrara, EPFL, Integrated Systems Laboratory, Lausanne, Switzerland

17:05: Ultra-low power digital processing for medical applications
Author: Marc Morgan, CSEM: Swiss Center for Electronics and Microtechnology, Neuchatel, Switzerland

17:30: end of the workshop

Explanation: the name of the speaker is underlined

Design and optimization of remotely powered RFID systems and sensor nodes

Catherine Dehollain
Ecole Polytechnique Fédérale de Lausanne (EPFL), RF IC group
SCI STI CD, Station 11, CH-1015 Lausanne, Switzerland
E-mail: catherine.dehollain@epfl.ch
www.ultrasponder.org
rfic.epfl.ch

The aim of this presentation will be to explain how it is possible to implement remotely powered RFID systems and sensor nodes. Clear distinction will be done between near field region (frequency range up to 100 MHz) and far field region (frequency range higher than 100 MHz).

The first part of the talk will be dedicated to the remote powering operation which allows obtaining an unlimited life time of operation of the passive tag or of the sensor node as no battery is used in the tag or in the sensor node. The AC input signal is transformed in a DC signal thanks to the rectifier. The energy is stored in a large capacitor connected at the output of the rectifier. The supply voltage of the tag or of the sensor node is provided by the voltage at the accesses of this capacitor. An equivalent electrical model of the rectifier will be presented. It will be shown that this model fits well with the measurements.

The second part of the talk will be dedicated to the half-duplex wireless communication. The uplink communication from the tag to the base station, also called reader or interrogator, is based on the modification of the input impedance of the tag (or of the sensor node) connected to the antenna according to the information to be sent from the tag to the reader. This uplink communication is called backscattering for electro-magnetic coupling between the tag and the reader, and load modulation for magnetic coupling. It will be shown why this technique is efficient to decrease drastically the power consumption of the passive tag and of the sensor node. An example of implementation in CMOS SOS technology of a RFID system operating at 2.45 GHz will be given.

In Vivo Ultrasonic Transponder System for Biomedical Applications

Catherine Dehollain, Francesco Mazzilli, EPFL, RF IC group, CH-1015 Lausanne, Switzerland
E-mail: catherine.dehollain@epfl.ch

Healthcare methodologies are constantly evolving due to the research and technology advancements made in the field of sensing and monitoring, promoting the use of wearable wireless devices for clinical applications. This opens the way to promising possibilities in terms of **prevention** and **treatment** of **patients requiring continuous surveillance or therapeutics**. **The EC FP7 Project ULTRAsponder** consists of a group of scientists, engineers and medical doctors, and aims at developing a new system with a very high degree of **reliability and accuracy of the clinical data**, while providing the patients with **high level of safety and user friendliness**.

Though the project intends to propose a general solution to several possible pathologies, such as acute diabetes, epilepsy and other debilitating neurological disorders, it focuses its efforts on one **demonstrator devoted to chronic cardiac diseases, and in particular Cardiac congestive Heart Failure (CHF).** For this specific application, **continuous monitoring** is particularly important to follow the day and night heart activity, thus allowing to understand **how the heart reacts** to different kinds of **stresses**, to different kinds of **activities** and to different sorts of **medications**. A continuous monitoring of a patient can also give the physicians the possibility to make a **direct comparison** of the actual patient condition with a past condition (one day, one week or one month earlier). Therefore continuous monitoring is a major leap forward in the diagnosis and the treatment of CHF.

ULTRAsponder aims at developing exclusive technologies based on **ultrasonic telemetry techniques**, for communication between one or several sensors deeply implanted in the human body (**the transponders**) and an external **control unit** which is used for both **wirelessly recharging** the implanted devices and **transmitting the received information** to the external world. The **key objectives** are the following:

- To develop innovative wireless data and energy transmission techniques for ultra low power sensor/actuator nodes immersed in aqueous media,
- To achieve small footprint, high flexibility, modularity and generality, which can easily be adaptable to any implantable microsystem,
- To perform acoustic (ultrasonic) wireless half duplex data transmission,
- To enable local signal processing capabilities to reduce transmission time and data load,
- To develop ultrasonic transponders intermittently or continuously monitoring parameters for biological applications, where considerations are given to miniaturization, power consumption, functionality, production and cost aspects,
- To prove the concept by developing a new technology for a network of ultra-low power transponders deeply implanted inside the body for long term periods,
- To assess the overall system in a real environment for a particular application aimed at measuring physiological parameters and correlating them (data fusion) to perform advanced diagnostics.

Coordinator of ULTRAsponder: Dr. Catherine Dehollain
EPFL, Faculty STI, RF IC Group, Station 11, Building ELB, CH-1015 Lausanne, Switzerland.
E-mail: catherine.dehollain@epfl.ch Tel: +41 (0) 21 693 69 71 http://www.ultrasponder.org

Ultrasound backscattering for deep-implanted devices: communication and energy challenges

Dominique Bovey
University of applied sciences of Western Switzerland
Yverdon School of Business and Engineering
Institute of Information and Communication Technologies
Yverdon, Switzerland

Implanted devices until now had two disadvantages: if equipped with a non rechargeable battery, either surgical intervention was necessary to change it periodically, or the device had to be implanted in relatively "shallow" locations, to enable recharging through radio-frequency.

Radio-frequency for in-body communication is problematic: if UHF (decimetric wavelength) it suffers high attenuation through the tissues (HF); at low frequency the inductive transmission offers also quite short ranges. Communicating back through RF is also a challenge because relatively high power has to be transmitted back to the outside.

Use of ultrasound solves the power transmission issue as in-body acoustic propagation suffers much less attenuation than RF; ultrasound enables a much longer propagation path, allowing enough power to recharge a micro-battery. The communication issue is overcome by transposing to acoustic transmission what is done in radio with the RFID; we have an external exciter, applied to the skin, which energises the implanted transponder. The acoustic impedance of the transponder's piezo transducer is modulated by the message to be read back by the exciter. This way the exciter has to handle an AM signal, modulated with very low depths. The acoustic acoustic levels involved make this compatible with medical standards.

In vivo ultrasonic transponder system for biomedical applications

J Bergsland[1], R Receveur[2], G Leogrande[2],
K Haugaa[1], T Edvardsen[1], W Zahid[1], I Balasingham[1]
[1]Interventional Centre, Oslo University Hospital, Oslo, Norway
[2]Medtronic Bakken Research Center, Maastricht, The Netherlands

In this presentation, an Intelligent Ultrasonic Transponder System will be described as is being developed in the context of the ULTRAsponder FP7 EC project. The presentation will focus on biomedical applications and in particular implantable medical devices.

Congestive heart failure (CHF) is the most rapidly increasing cardiac condition in the western world. CHF has high mortality and requires frequent hospitalization and intervention and follow up by medical services. Patients with CHF may in terminal phases be treated with cardiac transplantation or mechanical asistance, but prior to this close medical follow up and proper use of medication, restriction of salt and excessive intake of fluid is the clinical mainstay. Home monitoring have the potential of improving care thereby potentially increasing Quality of Life and decreasing cost of years gained by the patient.

The technology evolution in the last decade has promoted the development of new sensing and monitoring devices for healthcare, the use of wearable/wireless devices for clinical applications, and the emergence of several promising prototypes for managing patients (with acute diabetes, for treatment of epilepsy and other debilitating neurological disorders) and for monitoring patients with chronic cardiac diseases.

In spite of these advances, the design issues for deeply implanted devices remain numerous, especially miniaturization and power consumption challenges which are related. In addition, because of the body's dielectric nature, communicating with implants that are located deep within the body, using conventional techniques like Radio Frequency (RF), may not also work effectively. Another important concern, always associated with radio communication, is the electromagnetic compatibility. It is becoming more and more difficult to ensure a radio communication characterized by a high immunity to external radiators.

ULTRAsponder is therefore aimed at developing systems and methods, not using RF or magnetic telemetry with their crippling limitations, but acoustic waves (ultrasonic), for communicating with, and energising efficiently a network of transponders that are placed deep within a human body. Such systems are small and light, allowing them to be placed either by using open surgical or minimally invasive techniques. A transponder may include one or more sensors for monitoring a variety of properties As part of a network, several transponders can communicate and exchange information to an external control unit, leading to complex biological application schemes. This project is also dedicated to external systems for controlling, energising and communicating with such a transponder network, and to methods using such systems. The external control unit serves, in addition, as a gateway for the entire system. First in vivo experiments with prototypes of the system are scheduled.

Detection of deeply-implanted impedance-switching devices using ultrasound Doppler

Jean Martial Mari, Cyril Lafon, Jean Yves Chapelon
INSERM, UCBL1, 151 cours A Thomas, 69424 Lyon, France

The ultrasonic detection and possibly powering up/control of remote devices such as deeply-implanted physiological recorders sets the problem of their localization and the adequate insonification of their piezo electric sensors. Rapidly changing the impedance of some of these latter modulates through time their reflectivity, which allows the device to slightly flash periodically and in particular situations to communicate with the exterior. A method is proposed which enable to use this basic flashing ability to localize the device in the imaging plane by assimilating the flashing to an apparent movement, and enable further accurate focalization, and optimized communication if required.

An ultrasound color Doppler sequence is performed using a programmable scanner equipped with a custom probe imaging at 5 MHz a controlled piezo sensor, and the RF data collected at 40 MHz using for different pulse lengths and flashing frequencies.

Results show that detection can be achieved when the pulse length is at least 100 ns long, with an optimum reached at 400 ns, and that the switching frequency of the device must be in the range of 0.5 kHz and 200 kHz, out of which the flashing is either too slow for the scanner or too high for the sensor. A brief study of the impact of the incidence angle also showed that the piezo electric component of the device can be detected over an angle window of around 40°.

Shockwaves and High Intensity Focused Ultrasound for the non invasive treatment of kidney stones and Prostate cancer

Emmanuel Blanc (C.T.O. EDAP-TMS), Lyon, France

EDAP TMS develops minimally-invasive therapeutic solutions for urology. By investing in research and development and by forming partnerships with internationally-renowned medical research institutions, EDAP TMS has been able to develop innovative technologies in the fields of extracorporeal shockwave lithotripsy (ESWL) and therapeutic ultrasound (HIFU).

Extracorporeal Shock Wave Lithotripsy is a non-invasive technique for disintegration of urinary calculi. Urinary tract stones are frequent as they affect 2-3% of the world's population with twice as many men affected than women. When affected by a urolithiasis, the chance of recurrence is around 50%. Since its introduction in clinical practice more than 20 years ago, ESWL has become the standard treatment for urinary calculi. This treatment reduces stones to sand-like fragments using shock waves created outside the body by a lithotripter, targeted directly to the stone. This method does not damage surrounding body tissue and only breaks the stone.

High Intensity Focused Ultrasound is a non invasive technique for the destruction biological tissue. At the end of the 80s, the French Institute for Medical Research INSERM and EDAP TMS, started a research program for the treatment of prostate cancer. Prostate cancer is a major public health concern since 36% of cancers diagnosed in men are prostate cancers. One man out of 8 will suffer prostate cancer before 75 years old. At the global level 700.000 prostate cancers are diagnosed every year and the trend is toward an increase of the incidence with life expectancy growing. Although very common, especially in older man, prostate cancer evolves relatively slowly and it is the 3rd cause of death by cancer although it is the most common cancer.

The therapeutic effect of HIFU is associated with the absorption of ultrasound energy into the tissue, which is converted into heat. Temperature elevation in the tissues depends on the absorption coefficient of the tissue. The biological changes that are induced by heating depend on the temperature reached and the duration of the exposure (the thermal dose). Above a certain threshold, thermal doses induce irreversible tissue damage in the form of coagulative necrosis. Cavitation effects are also involved in the process of tissue destruction.

Both ESWL and HIFU are mini invasive therapeutic solutions that allow curative and cost effective treatment approaches by preserving patient quality of life.

Remotely-Powered Telemetry of the Human Metabolism for Applications in Personalized Therapy

Sandro Carrara
Ecole Polytechnique Fédérale de Lausanne (EPFL), Integrated Systems Laboratory
CH-1015 Lausanne, Switzerland

On-line monitoring for diagnosis and/or treatment of patients with specific physiological conditions (e.g., heart, cardiovascular, cancer diseases) or convalescents is a key factor to provide better, more rationale, effective and ultimately low-cost health care. On-line monitoring is also required in professionals and recreational sportsmen training, as well as in elderly and/or disabled citizen care. The ultimate goal of improved health care on those subjects is the extension of their autonomy, the improvement of their comfort levels, their integration into everyday life, and the maintenance of their safety through embedded systems to alert emergency services in the event of a potentially dangerous situation (e.g. the public-transportation drivers).

Some systems for on-line monitoring are available in the market. They use wearable devices (accelerometers, heartbeat monitoring system, etc) but they do not measure metabolites. The only available real-time, implantable/wearable systems for metabolic control are limited to glucose monitoring and used only by diabetic patients. However, many other molecules present crucial relevance in human metabolism in chronic patients. So far, there are no available implantable/wearable systems for multi-metabolites, real-time, on-line monitoring of the human metabolism. Thus, the aim of this keynote talk is to present an innovative concept for multi-metabolites, highly integrated, fully implantable, and real-time monitoring systems for human metabolism.

The considered metabolic molecules are glucose, lactate, cholesterol, ATP, and others. To pursue their detection, an innovative technology is discussed. The new approach is obtained by integrating nano/bio/micro/CMOS/SW/RF systems in three devices: (i) a fully implantable sensors array for data acquisition; (ii) a wearable station for remote powering and signal processing; (iii) a remote station for data collection, elaboration and storage. The major breakthroughs are in the areas of: (i) nano-sensors; (ii) software design for signal analysis; (iii) HW/Bio co-design; (iv) multi-panel metabolites detection; (v) fully implantable sensors; (vi) remote powering for biomedical implants.

Ultra-low power digital processing for medical applications

in the frame of the FP7 European ULTRAsponder project
Marc Morgan
CSEM: Swiss Center for Electronics and Microtechnology
Neuchatel, Switzerland
E-mail: marc.morgan@csem.ch

The ULTRAsponder core System-on-Chip (SoC) is presented along with the low power features which were designed into the SoC. This circuit was designed in the early stages of the ULTRAsponder project in order to have prototypes available to develop the software and an in-vivo demonstrator before the end of the project.

This System-on-Chip (SoC) contains:

- An ultra-low power processor designed for DSP and control type processing. The CSEM's icyflex1 processor with its dual MAC architecture was used. The presentation goes into some detail concerning the architecture and the low power features in the icyflex1 processor.

- The standard peripherals for a microcontroller (Timers, Watchdog, I2C, SPI, UART, GPIO, IRQ controller), a DMA controller to optimize power consumption during slow communication phases, a JTAG tap to support on-chip debug and an ultra-low power 32-kiHz RTC.

- A wide range of power management features to support power supplies from 1.0 V to 3.6 V and to power external devices.

- The support for 3 power modes (normal, sleep, hibernation) which allow the SoC to power down to 1 uW with a running RTC. Combined with a very low duty cycle, the ultra-low power SoC offers maximum flexibility as far as autonomy and processing power is concerned.